

THE UNITED STATES AND MALARIA: DEBITS AND CREDITS*

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FOR more than four centuries malaria was endemic in the United States and its founding colonies, highly so in some areas. The balance sheet over the years was a long list of debits with only here and there a credit item. Today the credits are amazingly numerous and large, and malaria has been eradicated. This paper is an attempt to look briefly at this balance sheet and to call attention to some items of interest.

DEBITS

Malaria, according to available evidence, did not exist in North America prior to its settlement by European colonists. *Plasmodium vivax* and *P. malariae* were probably introduced mostly by Spanish, English, Dutch, and French settlers and *P. falciparum* mostly by African slaves. That the malarial fevers were endemic in the homelands of the newcomers is beyond doubt, as witnessed by medical writings of the period.

In July 1526 about 500 Spanish colonists, including a number of Negro slaves, sailed from Puerto Plata in Hispaniola, now the Dominican Republic, to the Cape Fear River in North Carolina, then included in the name *Florida*, which was applied to most of the southeastern coastal lands. Scarcity of food and prevalence of disease, apparently including malaria, defeated this attempt at colonization. Whether a focus of malaria remained among the local Indians is not known. The area undoubtedly abounded in *Anopheles quadrimaculatus*, the local vector¹ of malaria.

English colonists brought malaria to Jamestown, Va., when they came in 1607. They also had the misfortune, in 1620, to receive the

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first cargo of slaves brought to the Colonies. The Africans were in a Dutch ship and doubtless many were malaria carriers.²

Jamestown residents suffered severely from fluxes and fevers;³ to what extent these included malaria is not clear. The site was certainly suitable for the breeding of the anopheline vector. Some authors believe that the disease was largely responsible for the transfer of the capital from Jamestown to Williamsburg in 1699.⁴ But Blanton⁵ stated that while he found references to agues which clearly were malarial, he was unable to substantiate "sweeping statements" about high incidence.

The early colonists in the North did not escape malaria. Noah Webster⁶ noted that about 40 or 50 years after the settlement of New England the infectious fevers were common. Some of these were intermittent agues. In those days, the word *agues* most often, but not always, referred to intermittent fevers. These intermittent fevers, or the "intermittents," were mostly *vivax* or *malariae malaria*. Remittent fevers, later called *bilious autumnal fevers*, probably were often *falciparum malaria*, but no doubt also at times typhoid fever or even yellow fever.

Duffy⁷ has quoted a 1690 Boston new report: "Epidemical Fevers and Agues grow very common, in some parts of the Country, whereof, tho' many dye not, yet they are sorely unfitted for their employments."

So the English colonies, south and north, were to a greater or lesser extent infested with malaria. In between were the Dutch, and they too reported the disease. Duffy⁸ stated: "The significance of malaria in colonial history can scarcely be overrated, for it was a major hurdle in the development of the American colonies. . . . Directly and indirectly, malaria was one of the most fatal of colonial diseases and shares with dysentery first place among the colonial infections."

These troublesome agues, brought to America in the 16th and 17th centuries, became widely endemic in the 18th century. Between 1700 and 1750 malaria occurred as far north as Maine, and in Vermont, on the shores of Lake Champlain; it had brisk but short seasons in Massachusetts.⁹ Rush¹⁰ stated that the disease was at times epidemic in the suburbs of Philadelphia, and also that it affected "two-thirds of the inhabitants of the southern states." Rush attributed the growing incidence of malaria in Pennsylvania to "the establishment and increase of mill-ponds" and to the clearing of woodlands without draining and cultivating them. Webster¹¹ reported that in Maryland "the earth was deluged with excessive rains, and intermittents were unusually obsti-

nate." Noah himself contracted a relapsing tertian in New York in 1798.¹²

Faust¹³ noted that by 1776 malaria was widely prevalent from Georgia to Pennsylvania, in the Mississippi, Ohio, and Tennessee valleys, the Western Reserve, the Indian Territory, in river bottoms of what are now Iowa, Nebraska, and Kansas, and in the Sacramento and San Joaquin valleys of California. It was moderately endemic in New England. So the United States was born in a highly malarious environment.

Malaria plagued both armies during the Revolutionary War. Warshaw¹⁴ mentioned a British Army surgeon who reported that intermittent fever put several entire garrisons out of action. Warshaw suggested that possibly the Yorktown surrender was hastened by the prevalence of this disease among British troops. Duncan¹⁵ stated that the siege of Yorktown ended providentially for the Americans, as their soldiers were also suffering severely from the fevers.

As the West was settled, after the war, malaria was so widespread that it could "truly be called *the American Disease*."¹⁶

The intermittent fevers continued to expand their pernicious influence for 75 years into the 19th century. For example, a fulminant epidemic of malaria in 1830 to 1833, beginning at Fort Vancouver and extending southward down to and along the banks of the Sacramento and San Joaquin rivers of California, decimated the aboriginal and settler populations. Saunders¹⁷ quoted Cook as stating that "three-quarters of the Indians who had resisted seventy years of Spanish and Mexican domination were wiped out in one summer."

Malaria became so common throughout the Mississippi Valley and in some southern areas that it was accepted as inevitable and normal. Ague, chills, and fever, as Ackerknecht¹⁸ pointed out, although objectively dangerous and burdensome had come to lose the character of a disease by social acceptance. "He ain't sick, he's only got the ager" was a typical comment of the period. Warshaw¹⁹ quoted the famous hygienist, Victor C. Vaughan, as saying that in his youth "in 1865, every man, woman, and child, at least within my range, shook with ague every other day."

Daniel Drake's extraordinary survey in 1850 of the diseases of middle America pointed clearly to malaria as the principal disease. Drake made a massive effort to determine the secret of malaria trans-

mission and missed it by only a hairsbreadth. As Smillie²⁰ remarked, "We who can see the answer so plainly long to reach out and help him. . . . He came so close!"

Drake, like Rush, believed that ponds, especially millponds and land that was cleared without drainage and cultivation were the prime sources of intermittent fevers. For example, he cited the case of Indianapolis,²¹ founded in 1820 and situated on recently cleared but undrained and uncultivated land. During 1821, there was an epidemic of intermittent fever during which nearly every one of approximately 600 residents became ill and 72 died. Drake repeatedly mentioned the prophylactic effect of drainage.²²

Malaria in the Mississippi Valley made a deep impression on Charles Dickens when he traveled from Cincinnati to St. Louis by river boat in 1842. In his *American Notes*²³ the author wrote of the place where the Ohio joins the great river as follows: "At the junction of the two rivers . . . lies a breeding place of fever, ague, and death . . . a dismal swamp, . . . with rank unwholesome vegetation, in whose baleful shade the wretched wanderers who are tempted hither, droop, and die, and lay their bones . . . a hotbed of disease, an ugly sepulchre. . . ." Later, in his novel *Martin Chuzzlewit*,²⁴ Dickens described the area as "a marsh on which the good growth of the earth seemed to have been wrecked and cast away, that from its decomposing ashes vile and ugly things might arise . . . where fatal maladies, seeking whom they might infect, come forth at night in misty shapes, and creeping out upon the water, hunted them like spectres until day; where the blessed sun, shining down on festering elements of corruption and disease becomes a horror. . . ."

On his river trip, Dickens' face was "profusely ornamented with the stings of mosquitos" but he did not equate the insects with the misty specters rising from the water "seeking whom they might infect." Fortunately for Dickens, his journey was not made during the season of malaria transmission.^{25, 26}

John Macculloch,²⁷ an English physician, discussing those intermittent fevers in the United States due to the noxious miasma called malaria wrote as follows: "What the fate of much of this new country may ultimately be in this respect, it is difficult to foresee, when we reflect on the numerous circumstances already noted, which modify the production and propagation of malaria, and where so much is yet

to be done as to alteration; though it is to be expected that no changes and no cultivation will ever bring into a state of salubrity, a country so abounding with alluvial plains, even in the interior, and so extensively the produce of its numerous and enormous rivers."

Obviously, Macculloch's gloomy prognosis was at fault. As Barber²⁸ stated and Ackerknecht²⁹ emphasized, it is noteworthy that the growth of the Middle West was not checked by malaria although the disease caused great suffering and many local temporary delays in development.

During the Mexican War, declared in 1846, malaria severely afflicted the troops, many of whom brought plasmodia back to their homes in the South and along the Atlantic seaboard. So, too, as Faust³⁰ noted, in the Civil War, malaria took an active part, causing high morbidity rates and many deaths in both armies. Carriers returning to their homes disseminated the disease widely throughout the South and Midwest and as far north as Massachusetts and Connecticut. Undoubtedly the war greatly intensified malaria endemicity in the United States.

The Reconstruction Period also witnessed an increase in the incidence of malaria, and there seems no doubt that this anemia-producing disease was an important factor in the slow recovery of the South. Less potent in the North, malaria was still a problem in some areas. For instance, the late Alan Gregg³¹ wrote that his parents left Connecticut in 1882 for Colorado because of the prevalence of malaria around their home in Hartford. Winslow³² reported that in the early years of his teaching at Yale there were 20 to 30 cases of malaria a year in the New Haven area.

Indeed, excepting a few places, throughout the length and breadth of our country, even spilling over into Canada, malaria in the 19th century was endemic and was the most common infectious disease in many localities. Quinine in large bottles stood on the clock shelf in thousands of homes, often beside a tumbler of water containing slippery elm bark, used as a "chaser." Barber^{33, 34} noted that the taking of quinine to alleviate ague was a daily ritual, but it was usually not taken for prophylaxis, because most of the victims believed that nothing could be done to prevent the seasonal chills and fevers of ague.

The incidence of malaria in the United States probably reached its climax about 1875;³⁵ after this it began to decline, especially in the North. But it remained an important hazard to health in the South well into the 20th century. For example, in 1914 von Ezdorf in a survey

of eight southern states estimated that there were about 600,000 cases of malaria in a population of 15 million.^{36, 37} In 1919 Carter stated that through 1917 the annual loss to southern industry and agriculture due to malaria was over \$100 million. About 20 years later Williams,³⁸ after a careful survey which he was so well qualified to carry out, reported that death, disability, and unproductiveness caused by malaria were costing the South no less than \$500 million annually.

Even falciparum malaria was intense enough in some communities to account for cases of blackwater fever. I recall that in the summer of 1924 in Lee County, Ga., as S.T. Darling's assistant in a Rockefeller Foundation training and research center, I saw two cases of blackwater fever. In the years 1923 to 1924, in Southern Alabama and Georgia, I surveyed many communities, colored and white, in which malaria was a dominant factor in producing ill health and economic stagnation.

In 1941 Faust stated that malaria was indigenous in 36 states.³⁹ He listed as malaria-free only the New England states, West Virginia, North and South Dakota, Utah, Wyoming, Montana, and Nevada.

As late as 1935 there were about 4,000 deaths from malaria in the United States. Ten years later the death toll had fallen to 400 and by 1952 it was down to 25. Finally, in 1965, only two deaths in the United States were due to malaria and both were from infections acquired overseas.⁴⁰

Memories are notoriously short, but perhaps this brief résumé of malaria debits over the years will contribute toward an understanding of the magnitude of the problem that existed in this country. The bills presented by malaria were enormous and they were never paid by outsiders. To be sure, they were discounted to a considerable extent by climate and certain other factors.⁴¹ But mainly, as described in the next sections of this paper, they were paid by the initiative and hard work of a generation of American malariologists and public health authorities acting on the basic discoveries of Laveran and Ross.^{42, 43}

CREDITS

The principal methods of eradicating malaria in the United States have been drainage—especially when followed by cultivation—drugs, larvicides, and adulticides. Screening has also had importance.

For centuries men in malarious areas of Greece and Italy had occasionally observed that draining pools and marshes tended to lessen the

incidence of intermittent fevers in surrounding communities. Probably a few scholars among American colonists had read of attempts to drain the Pontine Marshes for health and agricultural reasons, beginning in the days of the Caesars and carried on by Popes from John XV (985 to 996) to Pius VI (1775 to 1799). Also some of the English settlers must have been aware of drainage projects in the Fens which began in 1633 and effected a lowering of the incidence of tertian and quartan fevers among the Fen dwellers. Sternberg⁴⁴ cites an English writer named Graves who said, "The extinction of intermittent fever is the most striking, the most eloquent of all the modifications caused by drainage."

Similar drainage schemes which seemed to curb intermittent fevers were carried out in La Gironde, France, and in Holland. But I have not found records of colonists in the 17th or 18th centuries who mentioned drainage for fever control. However, in the 19th century there were numerous records of schemes for drainage that had the dual purpose of improving agriculture and controlling malarial fevers.⁴⁵

Boyd⁴⁶ quotes Daniell⁴⁷ in reference to a marked reduction in deaths from "autumnal diseases" following an improvement in the cultivation of rice in 1817 in Savannah that reduced the breeding area of the mosquito vector. Boyd also cites the improvement in health following drainage in New York in 1832 and 1860, and in Indiana in 1879. Boyd further notes that in 1857 the state of Michigan adopted legislation to encourage drainage of swamps and lowlands, and that in 1874 a symposium was held by the American Medical Association on drainage and public health. Sternberg⁴⁸ states that the Connecticut State Board of Health reported in 1872 that drainage in Fairfield and New Milford had steadily and rapidly reduced the incidence of malarial diseases. Subsoil tile drains were first used in the United States in 1835 in Geneva, N. Y., for agricultural improvement but with dividends of better health.

Obviously, until 1900 most schemes for drainage in the United States and elsewhere were designed primarily to benefit agriculture. But about 1901 the discoveries of *Plasmodium* by Laveran in 1880, and of mosquito transmission of malaria by Ross in 1897 to 1898⁴⁹ began to be widely known and accepted by the medical profession. Thereafter the antimalarial benefits of drainage were stressed to an increasing degree.

In the 20th century drainage has been a major method for the control and eradication of malaria. For example, during the depression years of the 1930's about 33,655 miles of ditches were dug in 16 south-eastern states, which removed about 544,000 acres of anopheline breeding surface.⁵⁰

The second major means of eradicating malaria in the United States is the use of drugs, mainly cinchona bark (1630 to 1830) and its alkaloid, quinine (1820 to 1930). The bark was often called Jesuit's bark or powder because Jesuit priests were the first to bring it to Europe and because their order was active in its distribution. The bark was used to cure ague in Rome as early as 1632, and in 1649 it was recommended for widespread use. Cinchona bark, first used in England about 1654 or 1655, was listed in the London Pharmacopoeia in 1677, about the time the great Sydenham became less timid in its use.⁵¹⁻⁵³

Not until 1692 did English medical texts give unqualified credit to cinchona bark as a cure for the intermittent agues. At that time the bark was still very expensive. So, in view of the lack of information about it, and its high cost, it seems likely that it was rarely used by American colonists before the 18th century. Until then sassafras and perhaps a horse-dung posset had to suffice.⁵⁴ Blanton⁵⁵ found no 17th century reference to cinchona bark in Virginia. However, it is possible that cinchona bark was first used in the Colonies in 1685 by Lionel Wafer, surgeon to some buccaneers who had stolen several bundles of the bark in Panama. Wafer recorded that he used it frequently in Virginia and elsewhere and that "it was the right sort."⁵⁶

Use of the bark was widespread in the Colonies in the 18th century, as recorded by Blanton and many others. Blanton⁵⁷ quotes a letter from William Byrd II (1674-1744), one of Virginia's most prominent citizens. Byrd wrote to a friend "We have swallowed the Bark plentifully but know not whether we should curse the Jesuits for filling our Mouths with so bad a tast (*sic*) or bless them for discovering so good a medicine. . . ."

Prophylactic use of the bark seems to date back to 1717, when it was used by the Chevalier de Bourneval at the siege of Belgrade.⁵⁸ It was recommended by Lind⁵⁹ and Buchan⁶⁰ in 1768 and 1781, respectively. Many American authors recommended the bark to prevent ague attacks—Drake,⁶¹ for example. From the 1830's cinchona bark and quinine sulfate became popular prophylactics against the malarial fevers.

"Dr. Sappington's Anti-fever Pills" were famous throughout the Mississippi Valley.⁶² In 1861 the U.S. Sanitary Commission published some rules for preserving the health of soldiers.⁶³ One stated that "It is wise and prudent, when ague and fevers are prevalent, that every man should take a dose of quinine bitters at least once every twenty-four hours. This will surely serve as a safeguard against an attack of the disease."

Quinine was extensively used in malaria control programs in the United States in the first quarter of the 20th century, and its limitations as a mass prophylactic became apparent. Then in the 1930's synthetic antimalarials became common. Quinacrine, otherwise known as atebirin, was highly effective as a prophylactic in World War II. The Board for the Coordination of Malaria Studies, beginning in 1943 with the helping hand of the National Research Council, supervised the most intensive program of drug research ever attempted, screening no fewer than 14,000 compounds for antimalaria activity. The development of chloroquine and primaquine was an important result of these studies. These drugs have had a useful role in malaria therapy and prophylaxis in recent years. But today, in some areas, the resistance of certain strains of plasmodia to synthetic drugs poses a serious problem.

The third means of eradicating malaria in the United States was the use of larvicides. Oil comes first on the list; its use to kill mosquito larvae dates back at least to 1793, when "common oil" was put in cisterns and rainwater casks to kill mosquitoes, as described in Dunlap's *American Daily Advertiser*, August 29 of that year, in Philadelphia. Kerosene as a larvicide was suggested in 1812 in a work by the English poet Robert Southey, entitled *Omniana* or *Horae Otiosiores*, published anonymously.⁶⁴ But such larviciding was not common practice until late in the 19th century after the famous entomologist, L. O. Howard⁶⁵ carried out pioneer experiments with oil larvicides. As a boy in Ithaca, in 1867, he had used oil to kill mosquitoes in a watering trough. Early in the 20th century came the spectacular successes of William C. Gorgas, in Cuba and during the construction of the Panama Canal, which greatly stimulated the use of oil larvicides. By 1925 a million gallons of oil were being used yearly in the United States to control mosquitoes.⁶⁶

Paris green came into wide use as a larvicide against *Anopheles* larvae following the experiments of Barber and Hayne in 1921.⁶⁷ Paris green was highly effective in the projects that eradicated *A. gambiae*

from Brazil in 1939 to 1942 and from Egypt in 1944 to 1945.⁶⁸ DDT and similar chemicals have now been added to the list of effective larvicides.

The fourth and no doubt the oldest means of eradicating malaria was the killing of adult mosquitoes. This was done first by hand, by swatters, and by smoke fumigation. Then came pyrethrum, and now there are the residual sprays, such as dichlorodiphenyltrichloroethane (DDT) and benzene hexachloride (BHC). Gorgas found that the killing of adult mosquitoes by handcatching and traps in workmen's quarters eliminated mosquitoes before they became infective.⁶⁹ Beginning about 1919 tremendous use was made of pyrethrum solutions, often sprayed by housewives who used the ubiquitous flit-gun. By 1935 more than 16 million pounds of pyrethrum flowers were being imported yearly into the United States, almost entirely for use in kerosene solutions for household spraying against mosquitoes. Considering the effectiveness of pyrethrum spraying in malaria-control experiments in South Africa⁷⁰ and in South India⁷¹ it seems to me that the household spraying in the 1920's and 1930's must have been a considerable force in curbing malaria in the United States.

Probably the earliest specific project for controlling malaria in the United States was that of Alvah H. Doty, Port Health Officer of New York in 1901. Dr. Doty diagnosed malaria in 20 per cent of the residents of one section of Staten Island. He then searched for and found *Anopheles* in their houses, and he discovered their breeding places. He then designed an anti-*Anopheles* campaign of screening, drainage, larviciding, and the use of larva-eating minnows. Vigorous treatment with quinine was given to the patients. Doty's project was successful.⁷²

The first citywide organized malaria control in the United States appears to have been undertaken in Ithaca from 1904 to 1908 following a malarial epidemic of more than 2,000 cases in a population of 13,000 in 1904. Blood-smear examinations were required of all suspected cases. A search for anopheline breeding places was carried out and vigorous efforts were made to eliminate them. The number of cases in Ithaca dropped to 1,000 in 1905 and to zero by 1908.⁷³

Other early attempts at the specific control of malaria have been recorded as, for example, those of J.M. Barnett in Dougherty County, Ga., beginning in 1902.⁷⁴

But the most important early American demonstration of malaria

control by antimosquito measures was that of Gorgas and his associates in Cuba (1901 to 1904) and the Panama Canal Zone (1904 to 1914). Of Gorgas' successes against yellow fever and malaria, Sir William Osler once remarked that nothing "in the history of human achievement" matched them.⁷⁵

Gorgas used prophylactic quinine, drainage, larviciding, screening, and the killing of adult mosquitoes. The malarial rate in the zone in 1906 was equivalent to 1,263 hospital admissions per 1000 population. By 1913 this rate had been reduced to 76 per 1000. Yellow fever which, with malaria, had defeated the French effort to dig a canal, was eradicated by 1907.⁷⁶ Malcolm Watson, a pioneer leader in malaria control in Malaya, described the work of Gorgas as "the greatest sanitary achievement the world has seen."⁷⁷

Gorgas was ably supported by his chief sanitary inspector, Capt. J.A. Le Prince and his assistant A.J. Orenstein, by the brilliant laboratory studies of S.T. Darling, and by the tireless field work of Henry Rose Carter of the U.S. Public Health Service.⁷⁸

But although the work of Gorgas and his colleagues had vividly demonstrated the possibilities of malaria control by anti-*Anopheles* measures, yet it did not prove that such measures were economically feasible in the average community in the United States. Indeed, it seemed to indicate just the opposite. This was also true of Watson's successes on rubber estates in Malaya. However, these victories over malaria did stimulate greater interest in the possibility of control. In 1912 and 1913, for example, the Public Health Service directed Doctors Carter and von Ezdorf to carry out malaria surveys in Virginia and North Carolina, and the following year the government, in its first antimalaria appropriation, made \$16,000 available to the service for similar surveys, about 20 of which were made in seven states.⁷⁹

Then, in 1915-16, at the invitation of the Public Health Service, the Rockefeller Foundation set out to determine whether or not malaria control by anti-*Anopheles* measures would prove economically feasible in the southern United States. Cooperative control experiments were made in four communities. These tests so successfully proved the economic feasibility and benefits of this type of malaria control that by 1922 no fewer than 163 counties in 10 southern states were cooperating with the Foundation and the Public Health Service in similar plans, and over 100 urban communities had set up control projects.⁸⁰

During World War I (1917 to 1919), there was a decided acceleration in the attack on malaria.³⁵ The Public Health Service organized control projects in 43 areas of military importance; it thereby protected about 1,750,000 civilians and 800,000 military personnel. In addition, military authorities spent about \$3.25 million for malaria control in cantonments in the United States.

After the war malaria seemed less important, and efforts to control it diminished. This slackening of effort, added to the characteristic tendency of malaria to increase in times of economic depression, was responsible in the early 1930's for the first significant upswing of malaria incidence in 50 years. But the threat was put down successfully, thanks to such efforts as: 1) development of a sound Tennessee Valley Authority (TVA) malaria control program; 2) coordination of malaria control activities by the Public Health Service and its plan for control on a statewide basis, under the guidance of L. L. Williams; and 3) a government relief program in which an average of about 211,000 men worked for six and one half years on antimalaria drainage in approximately 250 counties; under this program about 33,000 miles of ditch were dug, which eliminated approximately 544,000 acres of anopheline breeding surface in a 16-state area.³⁵

The Social Security Act of 1935 and its extension later in the same year provided funds for malaria surveys and control teams in 12 states. These teams of malariologists, entomologists, sanitary engineers, and technicians were of great value in the statewide control program.

During World War II (1940 to 1945) control of malaria was carried out vigorously by the Public Health Service and by military authorities in the United States. The Health Service organized an Office of Malaria Control in War Areas (MCWA) under the direction of Williams. A total of about \$31 million was spent in the vicinity of military areas by MCWA, more than 829,000 acres were larvicided, more than 19 million linear feet of ditches dug, and more than 84 million linear feet of ditches cleaned. The military forces spent approximately \$11.5 million on cantonment malaria control; they dug about 9 million linear feet of new ditches and cleaned almost 40 million linear feet. Over 6 million gallons of larvicide and 85,000 pounds of Paris green were used to kill anopheline larvae.⁸¹

In 1945 Congress provided funds for what was called the Extended Malaria Control Program (EMCP) proposed by Williams as a com-

prehensive nation-wide effort to combat malaria; this program made use of the newly available DDT, the value of which had been fully confirmed by practical use during the war and at the Orlando Laboratory of the Bureau of Entomology and Plant Quarantine under the direction of F. C. Bishopp, W. E. Dove, and E. F. Knipling.

The powerful insecticidal properties of DDT were discovered in 1939 in the Basle Laboratory of J. R. Geigy and Company by Paul Muller. For this discovery Dr. Muller received a Nobel Prize in 1948. The insecticide was used successfully in Switzerland as a dusting powder, called "Gesarol-5% Active Ingredient," against potato beetles in 1940 to 1941 and as "Neocide-5% Dust" in 1942 against lice and fleas. But because of wartime isolation of Switzerland these facts were unknown in the United States until late 1942. The United States Military Attaché in Berne, Major A. R. W. de Jonge, had noticed that shipments of Neocide were going to Germany, and he found out that the product was a powerful lousicide. He persuaded the Geigy Company to send samples to the United States and England, and these were received by the Geigy offices in New York and London in November 1942.⁸²

Geigy's office sent samples to Surgeon General Magee of the U.S. Army, the Federal Bureau of Entomology and Plant Quarantine, and possibly to other agencies. I recall with satisfaction that when the small sample of DDT labeled Gesarol-5% Active Ingredient that had been sent to the surgeon general was referred to my crowded desk without comment or descriptive leaflets. I did not drop it in the "circular file"; I sent it to M. A. Barber, who was studying mosquitoes in Florida and asked him to test it as a possible anopheline larvicide. Dr. Barber promptly did so; he thereby made the first such test in the United States and probably anywhere, and he reported that it was an excellent larvicide. Before long the Orlando laboratory reported that the new insecticide was a powerful lousicide and, later, that it had residual fatal effect on adult mosquitoes resting on treated surfaces. These reports, which were matched in England and fortified by information from Geigy, prompted Brigadier General James S. Simmons, chief of preventive medicine in the Office of the Surgeon General, and F. C. Bishopp in the Department of Agriculture, to urge immediate manufacture of the insecticide in the United States. Probably no individuals had more to do with stimulating early bulk production for the use of the Armed Forces

than Simmons and Bishopp. Pilot manufacture on a fairly large scale was started in May 1943 by the Cincinnati Chemical Works, partly owned by Geigy. Pilot production began at Geigy's plant in England about the same time. Thanks to active support by the Office of Scientific Research and Development and by the War Production Board, about 9½ million pounds of DDT (the nickname coined by the British Ministry of Health) were manufactured in the United States in 1944 and more than 47 million pounds in 1945.⁸³⁻⁸⁵ The history, pharmacology, toxicology, and uses of DDT were described in great detail in 1959 by Doctors W. J. Hayes, S. W. Simmons, and E. F. Knippling.⁸⁶

ERADICATION

In 1943 L. L. Williams proposed that the United States attempt to eradicate malaria from its borders.⁸⁷ In 1944 S. B. Freeborn made a similar proposal.⁸⁸ The word "eradication" in relation to malaria in the United States has been used as far back as 1915 by F. L. Hoffman,⁸⁹ and in 1922 the word had been used in Hardenburg's textbook, *Mosquito Eradication*.⁹⁰ But did Hoffman use the word with the meaning given to it by Williams and Freeborn? Possibly Hoffman and Hardenburg meant eradication of the serious public health hazard due to abundant malaria rather than the ending of all malaria transmission. In 1915 dearth of malariologists, paucity of knowledge about the local epidemiology of malaria, limitations of available control measures, and general ignorance about malaria would imply great boldness by Hoffman if he used the word *eradication* in the sense it had come to have by 1943. But Hoffman's plans were meticulously outlined, his National Malaria Committee was carefully chosen, and his influence was of considerable value. Moreover, in 1928 Hoffman stated that "the problem of complete eradication in the United States is far from having been solved. . . ."⁹¹ So perhaps Hoffman was really advocating what has now been accomplished.

In 1944 the National Malaria Society by resolution endorsed the idea of eradicating malaria from the United States. In 1946 the PHS, proposed a five-year eradication plan to Congress, which accepted it, so that in 1947 a National Malaria Eradication Program (NMEP) was started. The program was described as one of "attritional eradication"⁹² because it involved reduction of plasmodia in man by treatment, and concurrently in vector mosquitoes by spraying of DDT to a point

beyond which malaria transmission could not occur. The eradication of a vector was not economically feasible, and the eradication of a parasite from a community by mass treatment alone offered no promise of success.

The NMEP was vigorously implemented by the Public Health Service through its Communicable Disease Center (CDC) in cooperation with local authorities in the 13 states where malaria was endemic.⁹³ The total number of houses sprayed during the 1945 to 1952 period was 6.5 million and the total cost was about \$27.5 million, of which about \$9 million came from the states involved.⁹⁵ The CDC Technical Development Laboratories participated actively; they studied advanced procedures and solved operational problems. As malaria disappeared CDC assumed the task of surveillance to detect hidden foci of transmission and to prevent spread from imported cases.

Today all foci of indigenous malaria have been eradicated from the United States and Puerto Rico, and an efficient organization guards against any return of endemic malaria. A number of federal and private agencies have actively participated during the long period of research, training, and control required to accomplish eradication. The major participants will be briefly noted.

Federal Agencies

NAVAL MEDICAL RESEARCH INSTITUTE

Under the capable direction of Clay G. Huff, there has been basic research on malaria at the Naval Medical Research Institute (NMRI) over a 20-year period, which began in 1947 with appropriations that totaled about \$3 million.⁹⁴ Studies in the development, morphology, cultivation, and photomicrography of exoerythrocytic stages of *Plasmodium* have been especially important.⁹⁵

The relatively modest expenditures by the NMRI emphasize the fact that too little has been appropriated for basic malaria research throughout the world since the period of World War II. In view of so-called problem areas in the worldwide eradication campaign and of widespread endemicity in much of Africa, it seems illogical to view malaria as a "rapidly disappearing" disease, as one is tempted to do because of spectacular eradication in many areas.⁹⁶ Fundamental questions of insect and parasite immunity to insecticides and drugs, respectively, remain unanswered. More personnel in all categories trained in malariology are

needed. The Twentieth World Health Assembly urged that there be no slackening of effort in this direction and requested the director general to intensify fundamental malaria research.⁹⁷

WALTER REED ARMY INSTITUTE OF RESEARCH

In the past 10 years the Army Medical Service has spent approximately \$37.5 million for malaria research, in which the Walter Reed Army Institute of Research (WRAIR) in Washington has had a leading role.⁹⁸ Army interest in malaria research is logical because malaria has been a serious problem for the Armed Forces in Vietnam for a number of reasons, including a strain of *P. falciparum* that is resistant to chloroquine and other synthetic antimalarials. This has been a focal point of the institute's program.

ENTOMOLOGY RESEARCH DIVISION, U.S. DEPARTMENT OF AGRICULTURE

From 1937 through 1966 the Entomology Research Division of the Department of Agriculture spent about \$1.5 million on *Anopheles* research and an additional \$3 million studying control of other medically important insects, including an evaluation of insecticides of value also against anophelines.⁹⁹ The research program has included screening of insecticides and repellents. The studies of DDT, started during World War II, have been of immense value.

Public Health Service

The United States Public Health Service (USPHS) has been active in malaria control and research from 1912 to the present time; this, I hope, I have already made clear. Some day, I hope, the history of these activities will be told in detail; it will include not only the many outstanding achievements in research in the field, but also personal adventures in highly malarious environments at home and abroad, in peace and war, in Guatemala and Greece, Lido and Liberia, America and Anzio, and elsewhere.¹⁰⁰

Today the malaria activities of the USPHS are carried out by the National Institutes of Health and the Communicable Disease Center of the service.

NATIONAL INSTITUTES OF HEALTH

The National Institutes of Health originated as one of four bureaus set up in the USPHS in 1943 by act of Congress. The malaria activities of NIH have been assigned to the National Institute of Allergy and Infectious Diseases (NIAID) where basic malaria research has been remarkably productive. For example, the studies in chemotherapy of malaria begun in 1938 by L. F. Small and carried forward by G. Robert Coatney and W. G. Cooper and their colleagues, and now by G. M. Jeffery, have had basic significance.

During the past five years (1963 to 1967) NIH has appropriated nearly \$7.8 million for malaria research. Of this sum, about \$2.7 million has been spent directly by NIH; the balance has been disbursed as primary and secondary grants for malaria research in medical institutions.¹⁰¹

COMMUNICABLE DISEASE CENTER

The Office of Malaria Control in War Areas, referred to above, became the Communicable Disease Center (CDC) in 1946, with the primary purpose of solving disease control problems presented to it. In pursuing this goal CDC has achieved a notable record of applied research in malariology, especially in regard to insecticides and their use. Its research on malaria, in addition to the center's interest in other diseases, has been important to the United States.

In the fiscal years of 1944 through 1967, CDC has spent a total of approximately \$2.6 million on malarial research.¹⁰²

Until 1952, CDC also actively participated in the operational phases of the national eradication program (NMEP). Quoting Bradley³⁵ “. . . CDC established broad general policies in accordance with directives and appropriations of the Congress, while the States administered and managed the program.” The CDC Technical Development Laboratories worked out solutions of operational problems and developed procedures for improvement in economy and efficiency of field operations.

Recently CDC has been given responsibility for the technical administration of the malaria bilateral aid program of the Agency for International Development (AID). Primary planning and direction of programs and provision of funds remain functions of AID.

During the fiscal years of 1944 through 1967, CDC has spent a total of \$52,675,200 on the eradication of malaria at home and abroad, in addition to the money for research mentioned above. Of the total,

AID supplied about \$15.3 million, mostly in the fiscal year of 1967.

This cooperative arrangement between AID and CDC is the latest in a long line of bureaucratic changes in bilateral aid programs for the control and eradication of malaria in foreign countries.

After the announcement of 1947 of the Truman Doctrine for the containment of Communism, an American mission was sent to Greece. It included a program for cooperative help in controlling malaria. The Economic Co-operation Administration (ECA) took over this malaria project in 1940 and enlarged it to include malaria programs in Turkey, Burma, Thailand, Vietnam, Cambodia, Laos, Indonesia, Taiwan, and the Philippines. Then, in 1952, the Mutual Security Agency (MSA) succeeded ECA and was in turn succeeded by the Foreign Operations Administration (FOA), which also took over the IIAA program mentioned below and started malaria programs in Liberia and several other countries. A Technical Cooperation Administration (TCA) had been established in 1949 to implement Truman's Point Four objectives and it, too, participated in cooperative overseas malaria projects. TCA was included in the FOA takeover.

In 1957 the Mutual Security Act included the following declaration: "The Congress of the United States, recognizing that the disease malaria . . . constitutes a major deterrent to the efforts of many peoples to develop their economic resources . . . declares it to be the policy of the United States to assist other peoples in their efforts to eradicate malaria."

This pledge of 1957 has been generously implemented in spite of political ineptitude, instability, and bureaucracy at home and abroad. FOA was soon succeeded by the International Cooperation Administration (ICA). Then the Kennedy regime, not to be outdone, changed ICA into the Agency for International Development (AID) which has now enlisted the help of CDC, as already mentioned.

In all of the cooperative malaria programs abroad, the USPHS has participated actively. Amazingly, in spite of the burden of bureaucratic shuffling and myopia, the program of the United States bilateral aid to foreign countries for malaria control and eradication has been, in my opinion, a good investment.

The USPHS, through NIH and CDC, cooperates with the World Health Organization and the Pan American Health Organization in the problem of eradicating malaria from the world, which as mentioned below, is making good progress.

Data regarding expenditures by the United States agencies mentioned above in control of malaria overseas from 1947 to 1957 are not yet available to me. But the amount appropriated in the 10 years ending with fiscal year of 1967 totals more than a quarter of a billion dollars (\$231,271,000) used to assist approximately 30 foreign countries in their efforts to eradicate malaria.¹⁰³

This brief paper cannot do justice to the history of 55 years of antimalarial activity by members of the USPHS. A galaxy of outstanding malariologists comes to mind, gone but not forgotten: H. R. Carter, J. A. LePrince, R. H. von Ezdorf, L. D. Fricks, H. W. Van Hovenberg, T. H. D. Griffiths, M. A. Barber, W. H. W. Komp, Bruce Mayne, L. L. Williams, Jr., and Justin M. Andrews.

Mention should also be made of the many years of basic malaria research in laboratory and field by the staff of the Gorgas Memorial Laboratory in Panama, under the direction of Martin Young and his predecessors, not forgetting the illustrious career of Herbert Clark. This laboratory is financed by the United States.

Certainly, the story of the monies spent for malaria research, the results achieved, and the men involved over the past quarter of a century by the above mentioned agencies of the United States Government should be told in detail. Although it would appear that more attention should be paid today to research on malaria, what has been done constitutes a large credit item on the balance sheet.

Private Institutions

Research on malaria in private institutions, sometimes partly supported by government funds, has added important credits to the balance sheet. There are, for example, the studies on malaria of the Liberian Institute of the American Foundation for Tropical Medicine, the researches of William Trager at Rockefeller University, Leon Schmidt and his associates at Christ Hospital in Cincinnati, and now at the National Center for Primate Biology at the University of California, and those of several other individuals.

THE ROCKEFELLER FOUNDATION

One private institution that has had an important role in malaria research, training, control, and eradication is the Rockefeller Foundation, whose program may be briefly outlined as follows.

The Rockefeller Foundation, incorporated in 1913, became interested in malaria in 1914 when Wickliffe Rose, director of the International Health Commission of the Foundation, conferred with Ronald Ross in London, Malcolm Watson in Malaya, and the USPHS at home. As a result of those interviews, the foundation in 1915 to 1916 inaugurated a malaria program, which included support of cooperative demonstrations of malaria control and eradication, epidemiological investigations, research institutes, fellowships, and travel grants.

Malariology in 1916 was a neglected subject. Malariologists were few, the only antimalaria drug was quinine and its use was not standardized, and the control of malaria was mostly empirical and ineffective. Reduction of mosquitoes, as Ronald Ross pointed out, was unpopular among officials because of its expense, and it was ignored by doctors, who disliked the effort implied. Early stages of *Plasmodia* in man were hidden, and the habits and differentiation of *Anopheles* vectors largely unknown. The Rockefeller Foundation realized that while the control of malaria was theoretically simple, in practice it was difficult to initiate. Demonstrations were an obvious need, but a generous push was required to get them started. Hence the importance of experiments in the control of malaria such as those of 1915 to 1916 described above.

Successful control of malaria requires special organization and skilled personnel. So the foundation stressed the training of epidemiologists, entomologists, technicians and engineers, and the development of malaria sections within state and county health departments. As a result of this well-planned cooperation with the national Health Service and local authorities, malaria had almost disappeared from cities and larger towns of the United States by 1926—a remarkable achievement. No reasonable doubt remained that the control of malaria required a combination of measures, of which those directed against the vector mosquitoes were the most important. Naturally the rural areas presented a more difficult problem, but steady progress was made, largely because of efforts by county health units. The foundation had developed a standard plan for county malaria control and had cooperated with state and county authorities of the health services to make it effective.

In 1923, the foundation established a malaria research and training station in Leesburg, Ga., under the direction of S. T. Darling. Here: 1) the chief malaria vector of the southeastern states was sharply differentiated, a practical key for identifying its larvae was developed, and

its adult and larva behavior patterns were made clear; 2) the usefulness of splenic palpation in epidemiological surveys was demonstrated for the first time in the United States; and 3) the first important training center for malariologists in this country was established.

The present freedom of the United States from malaria is due to many factors but certainly, in no small measure, it stems from those years of active cooperation between the Public Health Service, state and county health departments, and the Rockefeller Foundation, all of which linked resources of men and money in malaria research and training and organization.

The Rockefeller Foundation also had a strong impact on the control of malaria overseas. In Europe, for example, stimulated by the foundation, cooperative experiments in Italy, Albania, Bulgaria, and Greece, under the brilliant leadership of L. W. Hackett, with the engineering skill of F. W. Knipe and the entomological studies of Ray Shannon, proved conclusively that antivector measures were more effective and economical than mass treatment with quinine, which was the usual method of control prior to the cooperative experiments.¹⁰⁴ These demonstrations, made possible by support from the foundation, were accompanied by intensive epidemiological studies and personnel training, and they undoubtedly laid the foundation of the postwar projects for control and eradication of malaria that have been so successful in Bulgaria, Corsica, Cyprus, Greece, Israel, Italy, Lebanon, Portugal, Rumania, Spain, and Turkey. Today malaria has been eradicated from Europe except for small foci in Greece and Turkey.

Other malaria projects stimulated, cooperatively supported, and often directed by the foundation were: the eradication of *A. gambiae* from Brazil and Egypt; the Sardinia experiment which eradicated malaria but not the vector;¹⁰⁵ and epidemiological, training, and control demonstration programs that prepared for and led to programs for eradication in Formosa (now completely free of malaria), in India, Ceylon, and the Philippines.

In March 1944 Fred L. Soper and I initiated what we believe was the first experiment anywhere to test the effectiveness of residual DDT for civilian malaria control on a practical scale in a community unit. This was directed largely by personnel of the foundation under the Public Health Sub-Commission, Malaria Division, Allied Control Commission in Italy. The experiment was made possible by the liberal

support of the surgeon of the Mediterranean Theater of Operations, Maj. Gen. Morrison C. Stayer, his preventive medicine chief, Col. William S. Stone, and Brig. George Parkinson, chief of the Public Health Sub-Commission. The experiment, expanded in 1945, had the cooperation of Italian malariologists and was successful. It led to the five-year national project which, under the direction of Alberto Missiroli, eradicated malaria from Italy.^{106, 107}

With support from the foundation, malaria investigation centers or government malaria institutes were established in Albania, Argentina, Bolivia, Brazil, British Guiana, Bulgaria, China (Formosa), Colombia, Cuba, El Salvador, Egypt, Greece, India, Italy, Mexico, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Puerto Rico, Spain, Trinidad-Tobago, Venezuela, and the United States.

Thus the Rockefeller Foundation led the way in the generous and continuing effort of the United States to help others to conquer malaria. The sharply focused cooperative programs of the foundation, which emphasized epidemiology, research, organization, training, and pilot control projects, prepared the way for the eradication of malaria at home and in a number of foreign countries. In instance after instance the foundation provided the catalyst, or the inexpensive mainspring, or the seed money that resulted in successful control of malaria. The total amount of money appropriated by the foundation (from 1914 to 1954) for malaria activities, exclusive of staff salaries, expenses, and overhead, was only about \$5 million. But the foundation's malaria program over the 41-year period was undoubtedly of fundamental importance and represents a large credit item on the balance sheet of transactions between malaria and the United States.

International Agencies Supported by the United States

The United States, in addition to financing its own bilateral foreign-aid malaria programs, has also supported certain multilateral agencies that have had programs for control or eradication. These include the Institute of Inter-American Affairs (IIAA), United Nations Rehabilitation and Relief Administration (UNRRA), World Health Organization (WHO), Pan American Health Organization (PAHO), and United Nations Children's Fund (UNICEF).

INSTITUTE OF INTER-AMERICAN AFFAIRS

In 1942 the United States cooperated with 17 Latin American nations to form what was called the Institute of Inter-American Affairs. The IIAA had a Health and Sanitation Division, under the direction of Maj. Gen. G. C. Dunham, which initiated a total of 163 malaria projects from 1942 to 1951 and spent some \$9.5 million on malaria control. The funds came largely from the United States.¹⁰⁸

UNITED NATIONS REHABILITATION AND RELIEF ADMINISTRATION

The United Nations Rehabilitation and Relief Administration was set up in 1943 as an international emergency organization. Its Health Division, under the direction of W. A. Sawyer, formerly on the staff of the Rockefeller Foundation, spent about \$168 million to alleviate the suffering of victims of World War II. Control of malaria was included in the program. For example, UNRRA distributed approximately 1.5 million gallons of DDT solution and 1.5 million pounds of DDT powder, as well as aircraft, spray pumps, vehicles, and expert staff.¹⁰⁹ The United States was a principal contributor to UNRRA.

WORLD HEALTH ORGANIZATION

The United Nations Economic and Social Council soon after its establishment appointed a Technical Preparatory Committee that met in Paris and set up an International Health Conference, which convened in New York in 1946. The conference formulated and approved the constitution of an international preventive medicine agency to be called the World Health Organization. A temporary WHO Interim Commission was organized to function until 26 member states of the United Nations ratified the WHO constitution. Ratification was obtained, and WHO was permanently established in 1948. From the outset WHO was interested in curbing malaria, and a Malaria Section, under the direction of Emilio Pampana, was established in the secretariat by the Interim Commission. The first Expert Committee of WHO was that on malaria, which met in Geneva in April 1947. In 1955, WHO initiated a worldwide malaria eradication program now administered by a Division of Malaria Eradication.

UNRRA transferred health funds and functions to WHO in 1947-8, and WHO also took over the functions of the *Office Internationale d'Hygiène Publique* and the moribund Health Organization of

the League of Nations. The Pan American Sanitary Organization maintained its identity but added to its functions those of a Regional Office of WHO.

Including sums allotted to the Pan American Health Organization (PASO), WHO in the 10 years ending 31 December, 1965, spent a total of \$74,629,000 on the eradication of malaria. Contributions of the United States to this total were about 61.1 per cent, or more than \$45.5 million.¹¹⁰ The PAHO has spent some \$21.37 million from its own funds for the control and eradication of malaria in the period from World War II through 1966. Of this sum approximately \$20.9 million has been contributed by the United States.¹¹¹

Justice cannot be done in this paper to the well-planned and administered WHO-PAHO Malaria Eradication Program and its concomitant malaria research programs. Except in Africa and in certain relatively small problem areas elsewhere, the programs are going well. With the exclusion of mainland China, North Korea, and North Vietnam, WHO reported that of a world population of approximately 2.62 billion about 1,635 million individuals live in areas originally malarious. As of December 31, 1966, about 963 million of the 1,625 were living in areas where malaria eradication was in either the maintenance or consolidation phase, i.e., where malaria transmission had been ended. Another 288 million were living in areas where malaria eradication programs were in progress. About 384 million were living in areas where no eradication programs were in progress.¹¹² In my opinion, the monies spent by the United States toward this program represent an excellent investment and a major credit item on the balance sheet.

UNITED NATIONS CHILDREN'S FUND

A United Nations International Emergency Children's Fund (UNICEF) was created in 1946, not as a specialized agency like WHO, but as an integral organ of UN. The name has been shortened to UN Children's Fund, but the original *UNICEF* initials have been retained. This agency has recognized that malaria has been one of the most important of all children's diseases and it has accordingly given important help to the eradication program. In the past 20 years UNICEF has spent about \$60 million in the fight against malaria. In one year alone more than 36 million people were protected from malaria by UNICEF supplies.¹¹³ What percentage of UNICEF malaria expendi-

ture was supplied by the United States is not known, but I estimate that it has been about the same as in the case of WHO. If so, the total United States contribution must have been about \$36 million.

From personal knowledge I can testify to the great importance and effectiveness of the UNICEF contributions to the worldwide malaria eradication program.

Time and space have not permitted an examination of the malaria control activities at home and abroad of private universities, research institutes, foundations, mission boards, commercial companies, and miscellaneous charities. But these activities too, have constituted a large credit item on the balance sheet. It would be interesting but it is not possible, to determine the total expenditures of the United States government and its citizens for malaria research, control, and eradication during the past 50 years. This total must be huge, but there are reasons for the belief that these monies have helped to remove the menace of malaria not only at home but also from the lives of nearly a billion of our neighbors, surely a large credit item on the balance sheet.

SUMMARY

Malarial fevers were probably not present in the lands now occupied by the United States prior to the arrival of colonists in the 16th century. They were introduced from Europe and Africa and from the West Indies and Central America by Spanish, English, Dutch, and French explorers and settlers, and by Negroes brought here as slaves. The "intermittents" became endemic throughout the Colonies in the 16th and 17th centuries, and intensely so in the 18th century. Thus the United States was malarious at birth.

The "autumnal ague" continued to expand and heighten its endemicity in the United States in the 19th century until about 1875, becoming so common, especially in the Mississippi Valley, that it was dubbed "*the American disease*."

After 1875, for about 55 years, until about 1930, the incidence of malaria declined. The reasons included: 1) increased drainage and land improvement; 2) fewer millponds; 3) increased use of cinchona bark and quinine sulfate; 4) increased larviciding, beginning about 1910, and increased use of household pyrethrum sprays, beginning in the 1920's; 5) organization of county and state programs of malaria control, research, and training by the Public Health Service and the Rockefeller

Foundation in cooperation with local authorities, beginning about 1915; 6) intensive control efforts in and around military areas during World War I; and 7) miscellaneous factors such as climate, movement of the population, greater numbers of cattle, and more screening.

In the early 1930's, when control efforts were relaxed because of a severe economic depression, the incidence of malaria increased. It became clear that, while certain natural forces, agricultural practices, and social changes had greatly reduced malaria transmission, these factors were not likely ever to eradicate malaria from the United States. Without organized and persistent efforts to control it, the disease would remain an economic and health hazard.

In 1937 L. L. Williams designed a plan for national malaria control on a statewide basis, and he later directed intensive programs of control around military areas during World War II. After the war the statewide program was greatly aided by DDT. So encouraging were the results that in 1946 and 1947 Williams and his colleagues in the Public Health Service designed and started a National Malaria Eradication Program. Now, after four centuries of endemicity, malaria has been eradicated from the United States and a vigilant organization, CDC, is alert to prevent its reestablishment. To this great achievement many agencies have contributed over the past half century, particularly the Rockefeller Foundation, the Entomology Research Division of the Department of Agriculture and, most important, the USPHS and its CDC and NIH. Local cooperation by county and state personnel has, of course, been one of the keys to success.

Not only has the United States dealt effectively with malaria at home but, beginning with the overseas malaria program of the Rockefeller Foundation in 1920 and continuing to the present day through the programs of ECA, MSA, TCA, FOA, ICA, AID, and MEP, and by contributions to the malaria programs of IIAA, UNRRA, UNICEF, WHO, and PAHO, the United States has been a powerful force in the worldwide decline in the disease. Although exact data are inaccessible it seems likely that the appropriations of the United States for overseas malaria control and eradication of the past quarter century have totalled more than half a billion dollars. As a result of this international cooperation, a worldwide malaria eradication program has been possible, directed by WHO. Today more than 960 million people who, a few years ago, were subject to malaria endemicity, are now

free of this threat to their health and welfare, and another 288 million live in areas where the disease is being vigorously attacked and transmission is coming to an end.

Because much of Africa remains highly malarious and because about 288 million people live in malarious areas not yet subject to eradication measures, it is logical that the United States should maintain an active interest in this disease. The most difficult phase of the worldwide program lies ahead.

In my opinion the United States has made an excellent investment in the control and eradication of malaria at home and abroad. But I question whether the monies spent for actual control measures have been adequately safeguarded by concurrent malaria research and training. Serious problems of resistance by *Anopheles* and *Plasmodium* to insecticides and drugs, respectively, have not been solved. Effective methods of dealing with vector anophelines that prefer to feed and rest out-of-doors have not been devised. Malaria epidemiologists, entomologists, engineers, and technicians are in short supply. This is the time to intensify, not reduce, United States emphasis on research in malaria.

United States agencies doing research in malaria include the Naval Medical Research Institute, Walter Reed Army Institute of Research, Entomology Research Division of the Department of Agriculture, Gorgas Memorial Laboratory, CDC, NIH, and several private institutions. Although complete data are not available, it seems likely that the total expenditures by the United States federal and private agencies for malaria research and training over the past 25 years in connection with civilian control and eradication at home and abroad, have totaled less than \$25 million. This total is considerably less than the appropriations of the Walter Reed Army Institute of Research (\$37.5 million) during the past 10 years for malaria research directed primarily toward solving the serious problems of malaria control and treatment among the Armed Forces in Vietnam.

To me there does not appear to have been a logical or practical ratio between the \$500 million spent trying to eradicate malaria and the \$25 million spent to find out how to do this most effectively and economically.

In conclusion, malaria in the past has been responsible for huge debits on the balance sheet of transactions in the United States. But the

credits now greatly overshadow the debits. Nothing in the history of public health, it seems to me, equals in determination, accomplishment, and generosity, the performance of the United States in its fight against malaria at home and abroad.

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